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TWO STAGE ANAEROBIC DIGESTION OVER SINGLE STAGE ON BIOGAS YIELDS FROM EDIBLE AND NON-EDIBLE DE-OILED CAKES UNDER THE EFFECT OF SINGLE AND CO-DIGESTION SYSTEM

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ABSTRACT

The objective of this study was to develop a two stage anaerobic digester for single and co-digestion of edible and non-edible oil cakes obtained from the oil extraction mill. The high protein rich oil cakes from edible mill the non-edible pongamia with major biological nutrients rich nitrogen and phosphorus were used as feed substrate. This waste is to generate energy in the form biogas using two anaerobic digester of D1 and D2 with 0.5m^3 capacity and covered by floating drum type gas holder where D1 for hydrolysis/acetogenesis and D2 for acetogensis/methanogenesis in a batch process with fixed retention time. The purpose of the research is to get more gas efficiency and the methane fraction with fixed HRT. This study is to examine with three phases using two stage anaerobic digester for single, co-digestion of edible/non-edible feed cakes as phase 1 coconut, phase 2 pongamia and phase 3 coconut/pongamia. The result shows that the performance of two stage anaerobic systems for single/co-digestion are found to be 10%, 5% and 12%, respectively more gas reported with higher methane production compare with single stage digestion. The total gas yield reported as 38 liters over 28.28 liters in single stage in phase 1. In phase 2 30.08 liters over 25.80 liters as in single stage pongamia and in phase 3 co-digestion of two stage yields of 44.65 liters compared to 32.24 liters in single stage co-digestion of coconut/pongamia.

Key words: anaerobic digester; biological nutrients; Biogas; De-Oiled Cakes; Co-Digestion System.

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1. INTRODUCTION

In a two stage anaerobic system for biogas production have some limitation for maintaining the process stability and to accommodate the micro biological changes in biomass. This research work focuses on the single digestion and co-digestion of two phase biogas process. The first stage consisted of hydrolysis and acidification, second stage consist of acetogensis and methanogenesis. The purpose of this division into stages was created of optimum conditions for acidogenic and methanogenic phases [1]. In anaerobic digestion, hydrolysis is often has some limitation in degrading biomass waste which are difficult to decompose, while in the degradation of easily decomposable substrates methanogenesis is the limiting phase. Due to the physical separation of hydrolysis/acetogenesis from acetogensis/methanogenesis [2]. Some of the potential advantages (i) Substrate inhibition, difficult to degrade in single phase may minimize in two stage, (ii) Substrate which is difficult to degrade and substrate which is easy to degarde may benefit in two stage [3], (iii) Due to different growth rates is substrate physical separation in two independently performing reactor is an option to enable high level degree of degradation in both the phases, (iv) Higher degree of degradation of acids is to be targeted in first phase/hydrolytic reactor, (v) Maximum conversion of the acids into biogas with a high methane concentration is to be targeted in a second phase/methanogenesis [4], (vi) Acid concentration can be adjusted in the hydrolytic reactor and transferred to the methane reactor results high methane content can be achieved in the biogas yield, (vii) When different substrates are used, high organic loading rates are possible with pH stability of the system, (viii) Volitile fatty acid developed in the substrate in the acetogensis may easily digest in the second methanogenesis stage may shorten HRT [5].

This research was to develop two stage anaerobic digestion for biogas production using two stage anaerobic digestion edible/non-edible and co-digestion [6] of edible/non-edible de-oiled cake from the oil extraction mill the reviled results in terms of biogas production and methane fraction were compared with the single digestion single stage of edible/non-edible and co-digestion of edible/non-edible de-oiled cakes as the work plan was shown in figure. The observed parameters are pH, temperature, substrate volume, volatile solid concentration and total concentration.

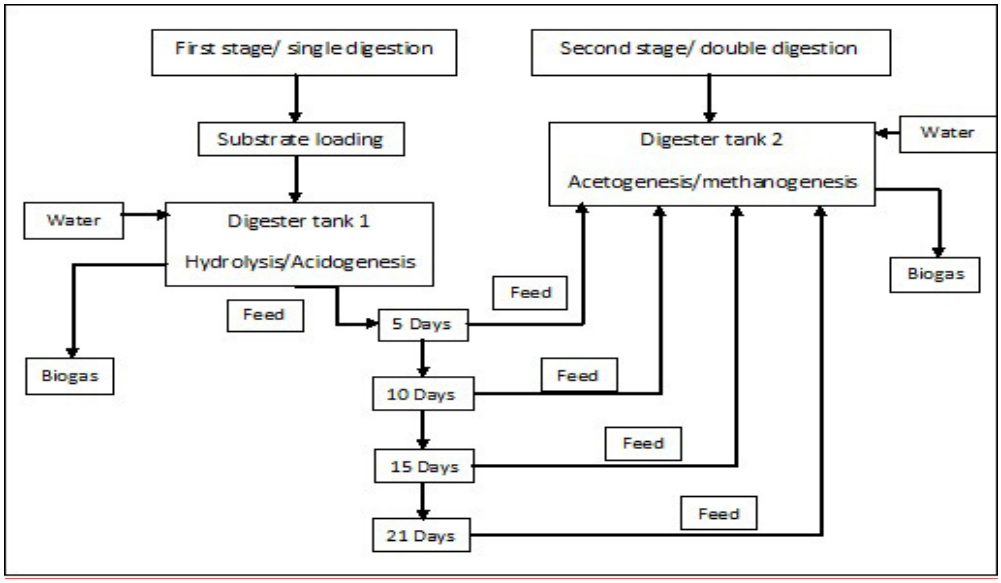

Figure 1 Anaerobic digestion of two stage digester with two digester D1 and D2 with respect to HRT

2. EXPERIMENTAL, MATERIAL AND METHODS

This work has examined on the single digestion of edible, non-edible de-oiled cakes compared with co-digestion of edible and non-edible oiled cakes in a two stage anaerobic digestion to get more biogas production and to get more efficiency from methane producing system. Using two digestion with batch process and fixed HRT as same loading rates.

The experiment was conducted in the department of mechanical engineering at Annamalai University in two digester as D_1 and D_2 with same 0.5 m^3 digester capacity and a gas collecting drum of 300 litres each as floating drum can move up and down. The digester gas outlet is at the top of the both the collector to measure of gas production using gas flow meter. The slurry outlet of D_1 was connected to the slurry inlet of D_2 as shown in schematic view is Figure 2 and photographic view as shown in Figure 3 (a) and (b). The work were conducted in 3 phases for each 21 days HRT using coconut de-oiled cake – single digestion two stage edible coconut oil cake (SD-TS-EDB-CT) in phase 1, pongamia de-oiled cake – single digestion two stage non-edible pongamia oil cake (SD-TS-NEDB-PA) in phase 2 and co-digestion two stage edible/non-edible of coconut/pongamia de-oiled cake – (CO-D-TS-EDB/NEDB-CT/PA) in phase 3 the obtained result are compared with single digestion single stage edible coconut oil cake (SD-SS-EDB-CT) [7] for phase 1, single digestion single stage non-edible pongamia oil cake (SD-SS-NEDB-PA) [8] with phase 2 and co-digestion single stage edible/non-edible of coconut/pongamia de-oiled cake (CO-D-SS-EDB/NEDBS-CT/PA) [9] in phase 3.

3. SUBSTRATE PREPARATIONS

Different oil seed cakes like coconut, pongamia was collected in a nearby village in Chidambaram were stored in a plastic bag at a room temperature these cakes were chopped into small pieces using mortar as pestle and blended prior to experiment as a waste / waste as 50:50. The blending mixed with waste/water to create the slurry along with 5% or 10% inoculums depends on feed properties before adding to the digester. This procedure was repeated for single and co-digested the initial pH of each slurry was noted and adjusted to optimize the observation on other parameters and the properties of feed material were determined as the method suggested by APHA [10] 2014.

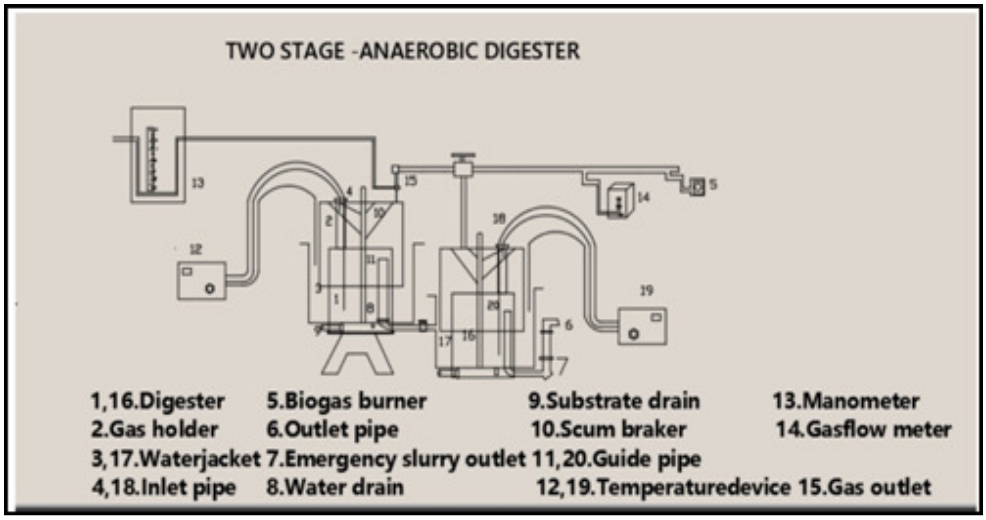

Figure 2 Schematic View of two stage anaerobic digester

Figure 3 (a) Photographic View of two stage anaerobic system with digester D1 and D2 before biogas formation

Figure 3 (b) Photographic View of two stage anaerobic system with digester D1 and D2 after biogas formation

4. RESULT AND DISCUSSIONS

This study aimed at the monitoring of process parameters like pH, biogas production and concentration of organic matter in the first and second stages respectively. Two alternating metabolic phases characterized by the production of different organic acids and gas amounts were observed in the first stage process. The digester operated in a batch process with the mesophilic range of 25° to 37°C in two stage fermentation system consisting of a hydrolytic/acidogenic first stage and a acetogenic/methanogenic second stage was established. The first stage of (SD-EDB-CT) loading rate of waste/volume is 30:70 and waste/water is 40:60 was loaded with an inoculum of fresh cow dung was fermented under anaerobic process with total solid Ts (mg/l) – 159 Vs (mg/l) – 34.5 moisture 42.6 and pH ranges from 7 to 7.6. The inoculum was loaded in digester was 5% along with the digester slurry of Ts 10.8 % with Vs 6.54 % as the feed material for digester D1. The table 1 shows AD of single/two stage edible coconut de-oiled cakes [11]. The figure 4 and figure 5 shows the cumulative and the daily biogas yield in phase 1.

Table 1 Anaerobic digestion of coconut oil cake single/two stage digestion

Particulars	Edible - Coconut de-oiled cake				
	Single Digestion single stage	Single digestion two stage D1	Single digestion two stages D2 from D1		
		21 day HRT	5th day of retention	10th day of retention	15th day of retention
Waste/volume	30:70	30:70	10:90 (30:70)	15:85 (30:70)	20:80 (30:70)
Waste/water	40:60	40:60	50:50	50:50	50:50
Inoculum %	5	5	5	-	-
Initial Ts %	10.8%	10.8	9.8	8.7	7.7
Initial Vs %	6.54%	5.75	6.75	7.25	7.39
pH range	7.2-7.6	4.5 – 6.5	7.2 – 7.9	7.5 – 7.9	7.1 – 7.9
C/N ratio	30:1	31:1	27:1	29:1	30:1
Temperature ˚C	30 to 37˚C	27 to 30 ˚C	27 to 30 ˚C	27 to 30 ˚C	27 to 30 ˚C
Hydro retention time(HRT) days	21	21	16	11	6
Daily gas production (liters /day)	0.4 to 3.35	0.5 to 1.7	0.7 to 2.1	0.9 to 2.75	1.0 to 3.39
Cumulative biogas production (liters/HRT)	25.28	10.75	27.25		
Methane Fraction %	28 – 67	35	68	69	75

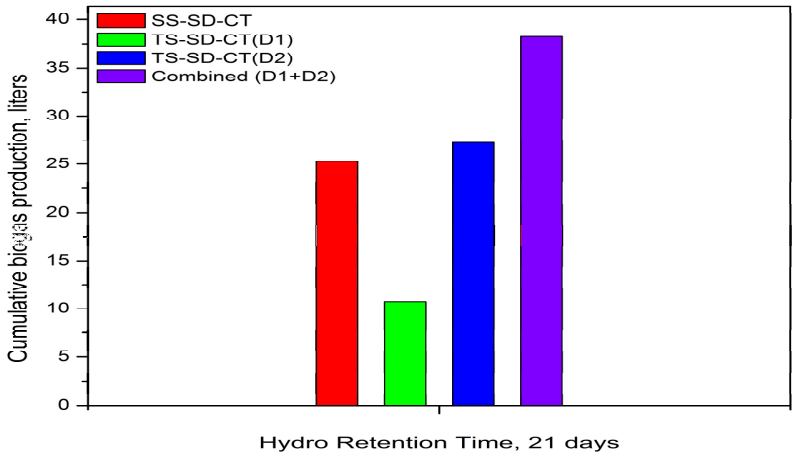

Figure 4 Anaerobic digestion of coconut oil cake single/two stage digestion (Cumulative biogas Vs HRT)

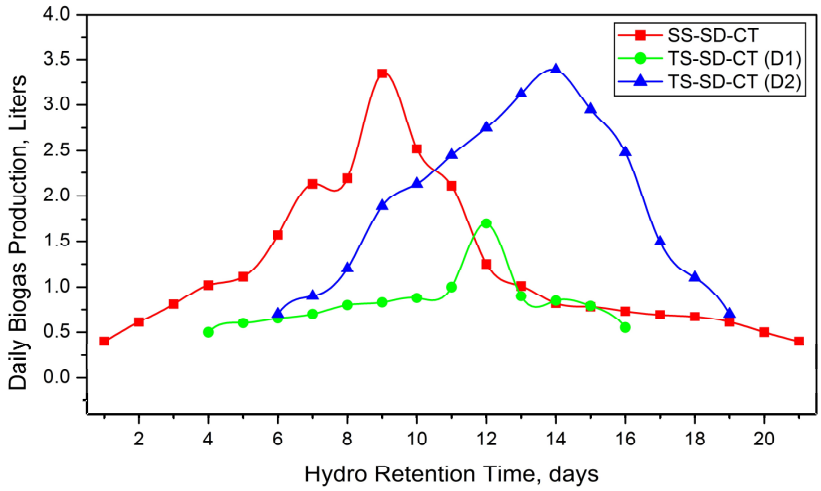

Figure 5 Anaerobic digestion of coconut oil cake single/two stage digestion (Daily biogas Vs HRT)

The experiment was conducted in batch mode after inoculation with fermented cow dung of 10% added with non-edible pongamia feed material as described in table 2. The reactor was operated for 21 days HRT in two digester as D1 and D2 to fulfill two stage anaerobic digestion process the slurry loaded in D1 for 21 days retention time after the hydrolysis process the displacement of slurry at the interval of 21, 16, 11 and 6 days as measured as waste/volume of 30:70, 10:90, 15:85 and 20:80 respectively. The gas volumes were calculated to a standard temperature and the cumulative and methane fraction of two stage digestion was compared with single stage digestion depicts the methane fraction and total biogas yield in single/double anaerobic digestion pongamia de-oiled cakes [12]. Figure 6 and figure 7 shows the cumulative and the daily biogas yield in phase 2.

Table 2 Anaerobic digestion of pongamia oil cake single/two stage digestion

Particulars	**Non-edible –Pongamia de-oiled cake**				
	Single Digestion single stage	**Single digestion two stage D1**	**Single digestion two stages D2 from D1**		
		21 day HRT	**5th day of retention**	**10th day of retention**	**15th day of retention**
Waste/volume	30:70	30:70	10:90 (30:70)	15:85 (30:70)	20:80 (30:70)
Waste/water	40:60	40:60	50:50	50:50	50:50
Inoculum %	10	10	10	-	-
Initial Ts %	10.8	11.7	10.5	8.75	8.5
Initial Vs %	6.54	6.75	6.5	6.75	6.95
pH range	6.5 – 7.6	6.9 – 7.7	6.2 – 6.5	5.9 – 6.5	5.5 – 6.7
C/N ratio	30:1	29:1	30:1	29:1	31:1
Temperature ˚C	32 – 40	29 – 39	27 – 29	25 – 37	27 – 38
Hydro retention time(HRT) days	21	21	16	11	6
Daily gas production (liters /day)	0.28 – 3.26	0.57 – 1.79	0.97 – 1.9	1.25 – 2.35	1.12 – 2.15
Cumulative biogas production (liters/HRT)	25.80	7.75	22.34		
Methane Fraction %	30 – 68	25 – 55	35 – 57	42 – 60	41 – 59

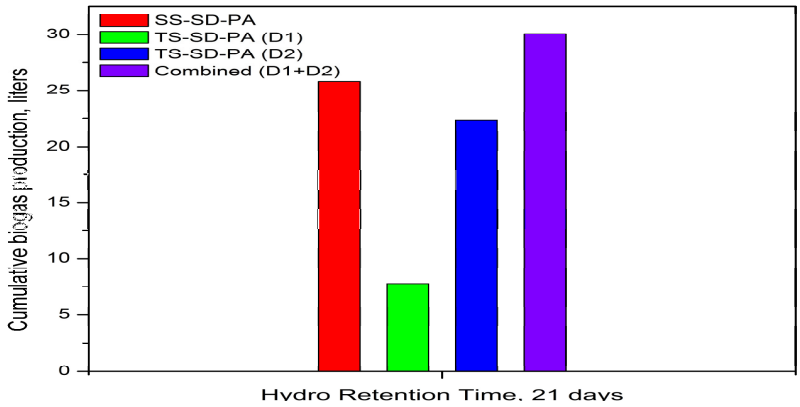

Figure 6 Anaerobic digestion of pongamia oil cake single/two stage digestion (Cumulative biogas Vs HRT)

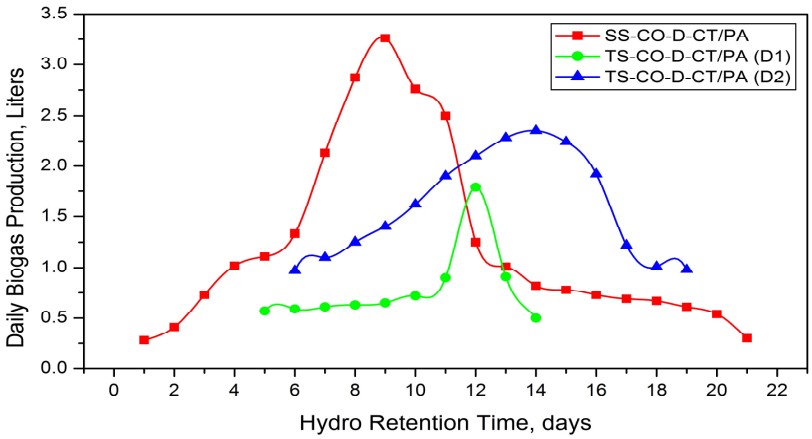

Figure 7 Anaerobic digestion of pongamia oil cake single/two stage digestion (Daily biogas Vs HRT)

The study reveals the co-digestion of single stage of which has less moisture 8% with 91% total solid in which 95% with volatile solid and the cake are fairly high in organic matter are the major nutrient result in a total gas yield of 32.24 liters with maximum 62% methane fraction in CT/PA co-digestion of single stage through a batch process for the HRT of 21 days. The first stage, a solid stage fermentation with acidic in nature inoculums were added along with fresh substrate. Digester from a single stage biogas reactor fed to the digester2 in terms of 5^{th}, 10^{th}, 15^{th} in days of digestion, the anaerobic co-digestion in two stage system where monitored in 21 days. In the first stage reactor D1, characteristic primary fermentation products were formed indicating that only hydrolytic and acidogenic process was active with minimum methane produce was observed.

During the experimental time, a periodic fluctuation of process parameters was observed in second stage. The pH value of the first stage was around 6 – 7, but stable pH value developed during the second stage between 7.5 – 7.8. It has been observed, in the biogas yield in single stage single digestion, as 32.24 liters and in two stage two digester with same feed volume. A cumulative gas yield was reported 44.65 liters for the same retention time. This study shows the importance of two stage co-digestion of edible and non-edible de-oiled cake reveals more than 12% gas yield with average specific methane potential was observed as 71% in the case of two stage digester [13]. The combination of two feed as co-substrate and two stages of a more biogas yield for the same feed material and same fixed HRT period. The table 3 shows the observation of biogas yield with single/two stage anaerobic co-digestion of

edible and non-edible de-oiled cake. Figure 8 and figure 9 shows the cumulative and the daily biogas yield in phase 3 of the work.

Table 3 Anaerobic co-digestion of coconut/pongamia oil cake single/two stage digestion

Particulars	Edible and non-edible – Coconut/Pongamia de-oiled cake				
	Co-Digestion of single stage	Co-digestion two stage D1	Co-digestion two stage D2 from D1		
		21 day HRT	5th day of retention	10th day of retention	15th day of retention
Waste/volume	30:70	30:70	10:90 (30:70)	15:85 (30:70)	20:80 (30:70)
Waste/water	40:60	40:60	50:50	50:50	50:50
Waste/waste	50:50	50:50	50:50	50:50	50:50
Inoculum %	5	5	5	-	-
pH range	7.8 – 8.9	6.5 – 7.0	7.5 – 7.7	7.7 – 7.9	7.6 – 7.8
C/N ratio	32:1	30:1	29:1	30:1	28:1
Temperature ˚C	28 - 38	27 - 37	25 - 37	25 - 37	25 - 37
Hydro retention time(HRT) days	21	21	16	11	6
Daily gas production (liters /day)	0.95 – 4.80	0.5 - 1.7	0.7 - 2.1	0.9 - 2.75	1.0 - 3.39
Cumulative biogas production (liters/HRT)	32.24	14.26	30.39		
Methane Fraction %	37 – 62	48	62	67	71

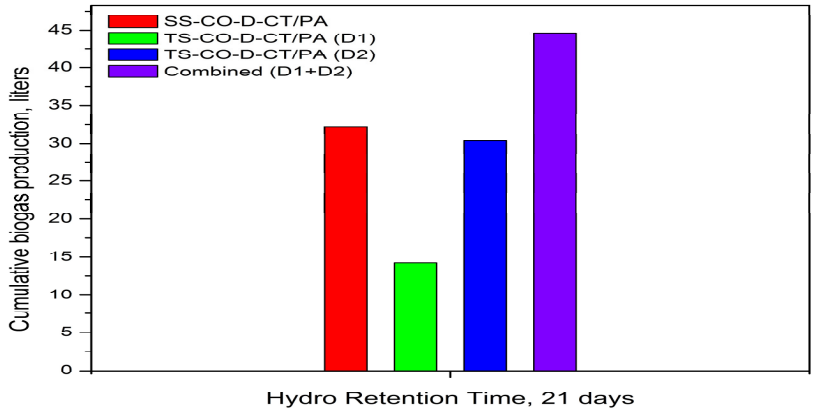

Figure 8 Anaerobic co-digestion of coconut/pongamia oil cake single/two stage digestion (Cumulative biogas Vs HRT)

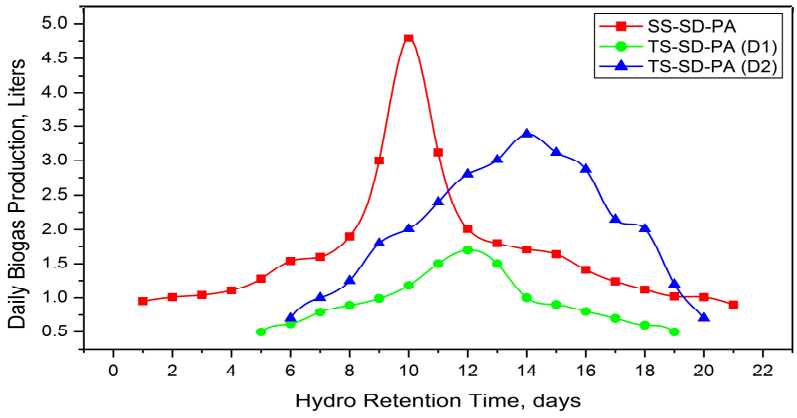

Figure 9 Anaerobic co-digestion of coconut/pongamia oil cake single/two stage digestion (Daily biogas Vs HRT)

5. CONCLUSION

- Biogas production from coconut de-oiled cake in two stages has been found to be higher at 10% compare to single stage digestion for a same retention period. Cumulative biogas production as reported as 25.28 liters compare with 38 liters in two stages. The percentage of methane content was found to be 67% due to the protein rich feed material and the metogenic activities on different digester. The specific methane fraction as reported as high as 71% in two stages.
- The result reveals the pongamia seed cake is the best source of biogas yield in a single stage anaerobic digestion only 5% more gas yield reported in a two stage digester for a same quantity of same feed material nearly 30.08 liters were produced compared to 25.80 liters was observed in a single stage. The highest CH_4 was observed in a single stage when compare to two stages due to the imbalance process stability.
- The result obtained from the co-digestion of two different waste compared with co-digestion of two stage anaerobic digestion of same feed material recover more biogas, the benefits of two stage co-digestion include: dilution of potential toxic compounds, improved balance of nutrients, synergistic effects of microorganisms, increased load of bio-degradeable organic matter and better biogas yield. It was observed that increased biogas yield in a co-digestion of two stage anaerobic digestion with CT/PM as 44.65 liters compared to 32.24 liters of a single stage of co-digestion same feed material for 21 days retention time. The average methane fraction was observed between 48 – 71% in two stage bio-degradeable digester compare to a methane content of 37 – 62% found to be in single stage co-digestion of same feed stock. Besides feed material used for co-digestion, digestion system is another important factor. For higher bio-degradeable waste, two stage digestion system was believed to be more advisable.

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